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Analysis

Development without energy? Assessing future scenarios of energy consumption in developing countries

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ABSTRACT

We analyze the relationship between economic development and energy consumption in the context of greenhouse gas mitigation. The main contribution of this work is to compare estimates of energy thresholds in the form of minimum energy requirements to reach high levels of development with output projections of per capita final energy supply from a group of integrated assessment models (IAMs). Scenarios project that reductions of carbon emissions in developing countries will be achieved not only by means of decreasing the carbon intensity, but also by making a significant break with the historically observed relationship between energy use and economic growth. We discuss the feasibility of achieving, on time scales acceptable for developing countries, both decarbonization and the needed structural changes or efficiency improvements, concluding that the decreases in energy consumption implied in numerous mitigation scenarios are unlikely to be achieved without endangering sustainable development objectives. To underscore the importance of basic energy needs also in the future, the role of infrastructure is highlighted, using steel and cement as examples.
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1. Introduction

With the publication of the United Nations Development Program report, “Our Common Future” in 1987 (WCED, 1987), impetus was given to the world community to address in an integrated manner the interlinked challenges of environmental degradation and sustainable development. In many ways it is the current world energy system that is at the nexus of these two issues. On the one hand – even though not incorporated directly in the Millennium Development Goals (MDG) – energy is undoubtedly essential for human development (GNESD, 2007). On the other hand, supply of energy in the past has been strongly connected to the combustion of fossil fuels and emission of GHG. From a developing country perspective, it is essential to understand how poverty alleviation and acceptable development levels that go beyond pure subsistence can be reached; at the same time the necessity of leap-frogging unsustainable development pathways that have been witnessed by developed countries in the past is highly obvious (World Bank, 2010).

Incorporating GHG mitigation into the discussion of sustainable development and requirements for energy system transformation implies a need for analyzing various scenarios for future greenhouse-gas emission pathways. To this end, integrated assessment models (IAMs) project future emissions, given a set of assumptions about population, economic growth and technological progress, and starting with data about the current state and past trends in the energy system. IAMs allow comparisons between baseline scenarios designated as business-as-usual (BAU) and those in which GHG mitigation policies are assumed (POL).

A broad range of studies is available in which mitigation costs in terms of foregone GDP or consumption[1] are evaluated under different circumstances (e.g. Clarke et al., 2009; Edenhofer et al., 2006, 2010; Luderer et al., 2012a; Weyant et al., 2006). Generally, macro-economic costs are found to be moderate in a first-best world with full techno-economic flexibility. This finding crucially depends on the ambitiousness of the climate target, assumed technological change, availability of technologies and the starting point of global mitigation efforts.

Analyses by IAMs have been at the heart of recent IPCC reports as for example the Fourth Assessment Report (AR4) (Fisher et al., 2007) or the Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) (Fischedick et al., 2011) and will continue to play an important role in the Fifth Assessment Report (e.g. Kriegler et al., 2012). Given the central role of IPCC assessments of published literature for international climate policy negotiations, it is important that IAMs provide robust estimates of future mitigation costs and transition pathways.

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[1] IAMs start only slowly to take broader aspects of development and sustainability into account, see e.g. Urban et al. (2007), van Vuuren et al. (2007), Bollen et al. (2009), and van Ruijven et al. (2008).

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When evaluating possibilities to avoid carbon emissions in the future, two options are at the heart of the current debate; cutting carbon-intensity by promoting carbon-free technologies like renewable energy technologies, nuclear energy or CCS, and improving energy intensity, either by higher levels of efficiency or through structural change.

Past studies have critically assessed the robustness of scenario analyses with respect to assumed energy- and carbon-intensity improvements. Pielke et al. (2008) argue that scenarios assessed for AR4 systematically overestimate the role of energy intensity improvements in the future and at the same time underestimate the carbonization dynamics of newly industrializing countries, like China or India.

In this paper we assess the role of energy consumption in scenarios of the future, particularly highlighting the essential role of energy in development processes. We start by evaluating the role of energy for human development by drawing on existing literature. We conjecture that economic development very likely requires a minimum level of energy.

We continue by asking whether energy consumption, as calculated in IAMs, is consistent with how energy has been related to development in the past.[2] We synthesize our insights from the analysis of historic patterns with the output projections of integrated assessment models (IAMs), particularly the ReMIND-R model, under both BAU and GHG mitigation scenarios. We evaluate how the relationship between energy use and economic growth is represented in these models, particularly for developing regions.

To better understand the nature of energy requirements in growth processes, we look at the role of infrastructure and related energy requirements. By means of extrapolation of historical patterns regarding the relationship between economic variables and infrastructure, we aim to provide a rough estimate of a lower bound of minimum requirements for energy use in the future.

Our analysis raises doubts that the role of energy in development processes is adequately considered in IAMs. We show examples in which multiple technological pathways are able to achieve a given global mitigation target according to the output of an IAM, but where the application of additional sustainability criteria, i.e. energy access tends to call into question the internal consistency of these mitigation pathways. These results may serve as a starting point for a discussion about the appeal of some of these pathways, in particular for developing countries. Therefore, we conclude with a discussion of our results with respect to their implications for future modeling exercises as well as climate policy, arguing that additional goals for sustainable development, such as access to energy, are closely related to economic development and hence must be included in the analysis of energy system transformation pathways.

2. Energy and Human Development

A substantial literature shows a robust positive correlation between per-capita income and energy consumption, at least at relatively early stages of development (e.g. Grübler, 2008; Schäfer, 2005). It has repeatedly been argued that due to increased demand for a clean environment and structural economic change, environmental pressures might decrease with rising incomes. However, this so-called ‘Environmental Kuznets Curve’ relationship that has been derived for certain local pollutants, such as SO_2 and PM (e.g. Grossman and Krueger, 1995; Selden and Song, 1994), does not seem to apply for energy use or CO_2 emissions (Luzzati and Orsini, 2009; Stern, 2004).

Consequently, the question of whether there is a minimal amount of energy necessary to allow for economic development arises. We consider here some bottom-up investigations of energy consumption patterns. A first, qualitative consideration would be that households must have access to some forms of energy for cooking food, and depending on the climatic zone, to energy for heating their homes. Beyond this ‘direct’ energy use, there are also ‘indirect’ needs for energy, e.g. to produce consumer goods or build up infrastructure (such as buildings and roads), which we will discuss in more detail in Section 4 of this paper.

One of the earlier works to look at this issue is that of Krugman and Goldemberg (1983) in which they determine a threshold of ~45 GJ/year for development to “acceptable” levels for Latin America, Africa and Asia. Their results come from bottom-up data, and include both commercial and non-commercial energy sources. A later paper by Goldemberg et al. (1985) attempts to determine energy needs for the future, given the ability to access an array of technologies to significantly enhance energy efficiency. Under those conditions, the authors arrive at a figure of approximately 1 kW as the rate of minimum average energy consumption (equivalent to ~31 GJ/year), considering both direct and indirect energy consumption, using Western Europe and Japan in the early 1970s as the target level for acceptable development. Considering only rural households, Pereira et al. (2011) set a level of ~10 GJ/year of direct energy consumption as a poverty threshold, using surveys of rural Brazilian households. This is not necessarily in conflict with the other references above, since indirect energy consumption can represent 50% or more of total energy, as shown by input–output analysis for Indian households, where similar primary energy consumption levels were found (Pachauri and Spreng, 2002), and because of a difference in defining the threshold (poverty vs. acceptable living standard).

IAMs also have begun to include consideration of energy access and minimal thresholds using a bottom-up model specifically developed to address the question of household energy needs; Daioglou et al. (2012) and van Ruijven et al. (2011) investigate regional variations in final household energy needs and find, although with large variations, a rough average in line with 10 GJ/capita. Energy access is the focus of the MESSAGE-Access model (Ekholm et al., 2010; Narula et al., 2012); current levels of household energy use in India, for example, are found to be less than 10 GJ per capita. Analyses of IAM output for different regions (China and India) and societal groups (urban vs. rural), show the same broad picture for household energy consumption (Krey et al., 2012).

A key point we wish to make with this paper is to make a distinction between minimal energy threshold for emerging from a state of absolute poverty, and the amount of energy needed to achieve high or very high development levels, e.g. in terms of the Human Development Index (HDI). A consistent feature of the literature is that energy needs for households continue to increase during the development process. If climate policies starkly reduce the amount of per capita final energy available for a developing country, there must be a clear description of how this is to be achieved, given large amounts of historical experience that indicates otherwise. Furthermore, the emphasis in the literature cited thus far has not been on a direct comparison between energy needs under business-as-usual vs. climate policy scenarios.

With respect to sustained economic development, it is clear that monitoring GDP growth rates alone is an insufficient condition for ensuring development. Broader measures of social and economic development such as the HDI,[3] although not without conceptual difficulties (see

[2] Please note that IAMs usually report consumption or GDP as development indicators and do not take broader concepts of development into account. We view GDP as at best a rough proxy since alternatives are not available in the IAM literature.

[3] The HDI is defined as a geometric mean of three different components of human well-being: life expectancy, education, and income. The indices are relative and normalized, such that for each component the individual country component value is calculated with respect to the minimum value in the sample, and then normalized to the maximum difference found in the sample. The education dimension is in turn made up of two parts, one being the mean years of schooling, the other being the expected years of schooling. A country potentially having the highest score across all three dimensions would have an HDI value of 1.0. The income dimension of HDI is included logarithmically in the index, acknowledging the decreasing return to well-being with increasing income.

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